CIE Reviewer's Report on the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment

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Prepared for:

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Executive Summary

The review of the 2017-2018 Pacific Sardine Stock Assessment developed by the Southwest Fisheries Science Center (SWFSC) STAT team was conducted by a STAR Panel, at the SWFSC Torrey Pines Court Laboratory, La Jolla, CA, from 21-24 February 2017. The main objectives of the Panel were to review two new approaches to the assessment of the Northern subpopulation of Pacific sardine (NSP): the first is the acoustic trawl method which was approved by a 2011 STAR Panel to provide an estimate of absolute abundance of the NSP, and the second a revised/modified model based assessment using Stock Synthesis model Version 3.24aa with a single index of abundance. Previous assessment approaches (e.g., T_2016 update) were also examined but not really considered to provide advice on the 2017 1+ biomass.

The assessment document and all background material necessary to conduct the Panel Review was made available almost two weeks in advance, allowing plenty of time to prepare for the meeting. In general, the Panel review adhered to the agenda provided to Panel members prior to the meeting, although the Chair was flexible and allowed diversion into other subject areas when they were relevant to the discussion. Several Panel requests for additional information or clarification of procedures were made to the technical team over the first 3 days. These requests were fulfilled promptly and to the satisfaction of the Panel. Much of the success of the Panel Review can be attributed to the technical team who did an excellent job of summarizing the information and providing the available data to address the issues at hand. The Chair kept the group focused on the topic being addressed, while at the same time allowing everyone, including observers, to express their views or contribute their expert opinion. A number of the attendees also provided valuable input during the course of the meeting.

The Panel concluded that neither of the two assessment approaches presented at the 2017 Pacific Sardine stock assessment was fully acceptable. The Acoustic-Trawl survey, while all agreed was likely the better approach, did not provide a reasonable mechanism to project the 1+ biomass forward approximately 1 year to July 1, required by management. On the other hand, the model-based approach had its own issues with the treatment age 0 in the model that were not fully resolved during the review. However, the Panel concluded that based on the available information the model-based was the better approach to provide the required estimate of biomass for management of the NSP Pacific sardine resource.

Many of the issues associated with the spatial-temporal distribution of fish and sample size, identified by the last review, continue to plague the 2017 sardine assessment. The Panel again raised concerns about the survey coverage, especially in light of the fishing industry's reports of large quantities of sardines in the nearshore water not surveyed by the research vessel. The limited amount of sampling conducted by the survey vessel and the samples available for ageing in

some years was a major surprise and concern for the Panel. Development of an age length key and estimating age distribution from such few samples is problematic. Furthermore, the use of a multi-year age length key due to the lack of sufficient samples is generally frowned upon by those involved in age structured assessments. Both the distribution of sardines and sample size need to be addressed in the near future.

There is an excellent opportunity to resolve some of the issues associated with coverage and sampling. During the meeting, there were several offers from the fishing industry to assist the STAT with improving the survey coverage to areas not covered by the large vessel and to work with the survey vessel to collect additional samples. These opportunities should be explored by the STAT, and if feasible, a coordinated program developed to ensure the efficient use of vessel time and effort, as well as the integration of industry-collected data into the assessment process.

The Panel was informed that the survey vessel time for the summer survey will be reduced from the current 80 days to 50 days in 2018. This represents a significant reduction in survey time and will at a minimum increase the variance of the biomass estimates and likely impact (reduce) the survey coverage and sampling time. This is another reason to explore collaboration with the fishing industry. The effects of this change/reduction in vessel time need to be evaluated if they are to continue into the future.

The Panel's report, to some extent summarized in this report, represents the consensus view of the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment and I fully concur with its content, recommendations, and conclusions. Overall, there were no major areas of disagreement between the STAT and Panel, nor among members of the Panel.

1.0 BACKGROUND

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). Under this mandate the NMFS (Office of Science and Technology) coordinates and manages a contract for providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer-reviews of NMFS scientific projects. The CIE reviewers are selected by the CIE Steering Committee and the CIE Coordination Team to conduct the independent peer review of the NMFS science in compliance with the predetermined Terms of Reference (TORs) for the peer review. In this case the "Terms of Reference for the groundfish and coastal pelagic species stock assessment review process for 2017-2018", provided as background material for the meeting, describes objectives and the roles and responsibilities of the participants. Two CIE reviewers served on a five-person Stock Assessment and Review (STAR) Panel, Chaired by Andre Punt, to review the 2017-2018 Pacific Sardine Stock Assessment. The Statement of Work (SoW) described in Appendix I identified the roles, responsibilities and reporting structure for the CIE reviewer. The reviewers are chosen on their expertise to provide an impartial, independent peer review without conflicts of interest, report on methods, outcomes and recommendations of the stock assessment review.

The Pacific sardine stock is assessed regularly (currently, every 1-2 years) by SWFSC scientists and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and models are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the SSC reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel reviews draft stock assessment documents and any other pertinent information for Pacific sardine, works with the stock assessment (STAT) team to make necessary revisions, and produces a STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery.

Each CIE reviewer is contracted to participate in the STAR Panel review meeting and to deliver an independent peer-review report to be approved by the CIE Steering Committee. This report, although generally consistent with, and similar to the STAR Panel report, is independent of the Panel report.

The specific tasks of the CIE Reviewers are to (See details in the SOW – Appendix 1):

- Review the background materials and reports prior to the review meeting
- Attend and participate in the panel review meeting
- After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs
- Assist the Chair of the meeting with contributions to the summary report, if required by the TORs
- Deliver their reports to the Government according to the specified milestone dates

1.1 Overview

A Pacific Sardine Stock Assessment and Review (STAR) Panel (Panel) was convened to review a draft assessment by the Stock Assessment Team (STAT) for the Northern Subpopulation of Pacific Sardine at the Southwest Fisheries Science Center, La Jolla, CA from February 21-24, 2017. The structure, responsibilities, goals, objectives and reporting requirements were defined under the terms of reference for the groundfish and coastal pelagic species stock assessment review process for 2017-18. In essence, the Panel reviewed three approaches for providing advice to management; two new assessment approaches and the default of updating the previous assessment. A list of attendees and the agenda are provided in the Appendices. It should be noted that because the CIE reviewer report is a standalone document, several sections of this report contain text that has been extracted almost verbatim from the STAR Panel report as the reviewer contributed to the document and feels it provides a good overview of the process and discussions.

Stock assessment team members, Drs. Paul Crone, Kevin Hill, and Juan Zwolinski presented a general overview of the assessment methodology for each of the different assessment approaches. Paul Crone first outlined the assessment history and philosophy, then moved on to focus on selecting an approach that was considered by the STAT to be most objective, i.e. the Acoustic Trawl Method (ATM) survey. In addition, because of the management schedule and fishing year, there is a requirement to provide the age 1+ biomass on July 1, 2017. The STAT provided results for two assessment approaches: (a) use of the summer 2016 Acoustic-Trawl method (ATM) survey biomass estimate and associated age-composition projected to 1 July 2017, and (b) a model-based

assessment (ALT) that provides an estimate of age 1+ biomass on 1 July 2017. Both were considered as viable options for estimating biomass.

Dr. Juan Zwolinski provided a general overview of the spring (March/April) and the summer (July/September) acoustic-trawl surveys; the former concentrated in the southern USA, and the latter had broad coverage from California to Canada. Methodologies were discussed, however, because an ATM methodology review is scheduled for January 2018, only in general terms. Much of this survey approach had been reviewed and approved by a STAR Panel Review in 2011. He also described the survey-based method for estimating/projecting the age 1+ biomass on 1 July 2017. The method involved estimating numbers-at-age on 1 July 2016 from the summer 2016 ATM survey from numbers-at-length using an age-length key (pooled data over multiple summer surveys), and projecting these numbers forward under natural mortality, growth, and adding the estimated recruitment for 2016. Recruitment for 2016 was based on the stock-recruitment relationship estimated from ALT model outputs. The spawning stock biomass for 2016 was estimated by back-projecting the summer 2016 numbers-at-age to 1 January 2016.

Kevin Hill and Paul Crone presented the data on the model-based assessment, as well the results from a draft assessment utilizing the Stock Synthesis Assessment Tool, Version 3.24aa. The major differences in Model ALT from the model on which the 2016 update assessment (T_2016) were starting the assessment in 2005 rather than 1993, excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices, estimating rather than pre-specifying stock-recruitment steepness, pre-specifying weight-at-age rather than estimating it within the assessment, assuming that selectivity for the ATM survey is zero for age 0 and uniform for age 1 and older, estimating survey catchability (Q), assuming that selectivity is age- rather than length-based, modelling ages 0-10yr rather than ages 0-15yr, assuming natural mortality (*M*) is $0.6yr^{-1}$ rather than $0.4yr^{-1}$ for all age classes and fitting the catch and ATM survey age-composition data (rather than the associated length-composition data). Unlike the 2016 and earlier assessments, the model ALT included additional live bait landings, which generally reflected a minor contribution to the total landings in California and was the only active sector in the US sardine fishery. However, model ALT did not include biological composition data from the live bait catches, given this fishery sector had not been regularly sampled in the past. Samples were available for only the most recent year of the time series modelled in the assessment.

The review and subsequent explorations of the assessment through sensitivity analyses were motivated primarily by the need for the survey-based method to provide an estimate of age 1+ biomass and its CV, to better understand the rationale for the changes made to the model on which the last full assessment was based that led to model ALT. The Panel had several comments and concerns regarding the ATM survey methodology and ways in which estimates of close-to-absolute abundance can be obtained. However, it was stressed

throughout the meeting that this was not a review of the ATM survey, since an ATM methodology review is planned in early 2018. Therefore, comments regarding the ATM survey and how estimates of abundance from that survey are constructed are reflected primarily in the Research Recommendations section of the report.

In the end, the Panel was not fully satisfied with either of the approaches used to estimate the age 1+ biomass on July 1, 2017. The ATM had problems with the approach used to project almost a year forward and the ALT model with the treatment age 0 in the model. These issues are discussed in more detail below; however, the Panel concluded that the ALT model was the better available approach to provide the required estimate of biomass for management of the NSP Pacific sardine resource.

The STAR Panel and the CIE reviewers thank the STAT for their hard work and willingness to respond to Panel requests, and the staff at the SWFSC La Jolla laboratory for their usual exceptional support and provisioning during the STAR meeting.

1.2 Goals and Objectives:

The specific goals and objectives for the 2017 Pacific Sardine Stock Assessment Review are those defined in the of groundfish and CPS STAR process document as follows:

1) ensure that stock assessments represent the best scientific information available and facilitate the use of this information by the Council to adopt OFLs, ABCs, ACLs, harvest guidelines (HGs), and annual catch targets (ACTs);
2) meet the mandates of the Magnuson-Stevens Fisheries Conservation and Management Act (MSA) and other legal requirements
3) follow a detailed calendar and fulfill explicit responsibilities for all participants to produce required reports and outcomes;
4) provide an independent external review of stock assessments;
5) increase understanding and acceptance of stock assessments and peer reviews by all members of the Council family;
6) identify research needed to improve assessments, reviews, and fishery management in the future; and
7) use assessment and review resources effectively and efficiently.

It is important to note that the following report to the CIE reflects my independent opinions and views on the issues and questions identified in the terms of reference, statement of work, and the above goals and objectives. The report is, however, generally consistent with the recommendations and conclusions of the

other panel members and CIE reviewers. Overall, there was general consensus among the panel members with no identifiable areas of disagreement.

2.0 Description of the individual reviewers' Role

The CIE reviewers essentially served two roles on the STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment. First, to participate as a full panel member in the review of the practices and procedures involved in the proposed assessment methods/approaches, and second to provide an independent review of the methodology and process.

To meet these requirements for the assessment of the Pacific sardine resource in 2017 a reviewer must have achieved recognition in several fisheries related fields. In this context, I am considered an expert in the assessment of small pelagic fish stocks, fisheries acoustics as applied to assessment of small and large pelagics, and their application to the management of the stocks. Currently, I am a senior Research Scientist with the Canadian Department of Fisheries and Oceans responsible for the research and assessment of large and small pelagic fish species. In addition, I am the scientist responsible for the acoustic program in my region of Canada and I have spent more than 25 years as the lead for small pelagic stock assessment program. I have a B.Sc., M.Sc., and PhD in fisheries related fields and have served on several international stock assessment review groups. Between 2010 and 2014, I was the Chair of the ICES North Sea Technical Review working group which provided quality control for all North Sea fish stocks assessed by ICES. Recently I was appointed Chair of the ICCAT western Bluefin tuna assessment working group.

My primary role was to participate in the 2017 Review as an informed expert and to contribute to the discussions and recommendations put forward by the STAT and the STAR Panel. Prior to the meeting, the stock assessment document was provided by the STAT team along with numerous background reports/documents on the fishery, methods, outputs and recommendations. The majority were read before the meeting so that well informed questions and discussions could be undertaken. Once the meeting began, my main focus was to be on the acoustic aspect of the assessment methodology; however, we were informed that because there will be a methodology review of the Acoustic –Trawl survey approach in January of 2018, much of the discussion will be deferred until. The meeting was still open to discussion on this subject, but most issues would be identified for investigation at the 2018 review.

Thereafter my focus shifted to the other areas of the review, participating in the discussions on the model-based assessment, major issues such as ageing, changes in mortality, the projection of biomass to July 1, 2017, the conclusions/

recommendations of the STAR Panel, contributions to the Panel Report and the preparation of an independent reviewer's report.

3.0 Summary of Findings for each term of Reference:

The summary presented below is an overview of the review and is generally consistent with the observations and results found in the STAR Panel Review Report. However, in several sections the text has been enhanced or is more inclusive to elaborate on specific issues. Prior to discussing the outcomes of the review associated with each TOR, I would like to make a few general comments regarding the documentation and the presentations. The stock assessment team (STAT) provided a good overview of the methodology and approaches described in the assessment document (Hill et al., 2017). The presentations by individual members of the team were informative and coherent. However, there were a number of cases where insufficient details were provided in the methods section of the assessment document for the Panel members to have a clear understanding about what or how something was done. This resulted in several extended discussions on the issue that could have been resolved with a few additional sentences in the assessment document. The STAT was very helpful in providing the details or the source of the details to the Panel where clarification was requested. Of particular concern were biological sampling protocols and the post stratification and analytical approaches used in the acoustic biomass estimation. Both involved extended discussions to clarify several areas of uncertainty.

The STAT team prepared and presented two new assessment approaches to the STAR Panel for review; One based on the outputs from an Acoustic-Trawl survey (ATM) as an absolute estimate of abundance, and the other an integrated model based method (SS3) to estimate biomass (ALT). Both methods were found to have merit but the former was obviously preferred by the STAT. The option to simply update the previous assessment (T_2016 to T2017) was not really being proposed or considered, although it was approved for management of resource by the 2014 STAR Panel. This was due to some undesirable features, such as extreme sensitivity to the occurrence of small fish in the ATM surveys, poor fits to the length-composition and survey data, as well as sensitivity to initial values for the parameters.

Although acoustic technology plays an extremely important role in the assessment, discussion on much of the acoustic methodology and assumptions was deferred. The Panel was informed that an acoustic methods meeting was scheduled for January of 2018 and that issues could, and should, be identified, but that detailed discussion of the issue would be postponed until the methods meeting. The assumption that the ATM was an acceptable approach was based on the 2011 Acoustic-Trawl Survey Method for Coastal Pelagic Species- Report

of Methodology Review Panel Meeting, conclusions that: “Overall, the Panel is satisfied that the design of the acoustic-trawl surveys, as well as the methods of data collection and analysis are adequate for the provision of advice on the abundance of Pacific sardine, jack mackerel, and Pacific mackerel, subject to caveats, in particular related to the survey areas and distributions of the stocks at the times of surveying. The Panel concluded that estimates from the acoustic-trawl surveys can be included in the 2011 Pacific sardine stock assessment as “absolute estimates”.

Finally, there was a preconceived, or biased, preference of which model approach was preferred by the STAT team. While most of the Panel agreed that the simplest approach was likely the better, the text of the document only identified the merits of a survey-based assessment and the drawbacks of a model-based assessment. This somewhat unbalanced overview was discussed early during the meeting and the team agreed to provide a more balanced overview in the assessment document. Ironically, in the end, it was the model-based approach (ALT) that was selected to provide the advice to management for 2017.

One constraint in the process was the necessity for the approach to provide a mechanism for projecting a biomass estimate for the start of the fishing year, in this case 1 July 2017. As happened in this review, the STAT and the STAR Panel agreed that the ATM was the better and simpler approach for providing estimates of biomass, but because of the issues associated with the projection method proposed for the ATM the panel was left with no alternative but to recommend the use of the ALT model to provide advice to management. Both approaches provided similar biomass estimates. Several methods to provide a suitable projection approach for the ATM were investigated during the meeting but none were deemed acceptable. Alternative approaches to resolve this problem are proposed in the STAR Panel report recommendations.

The role of the STAR Panel is to conduct a detailed technical evaluation of a full stock assessment to advance the best available scientific information to the Council. The specific responsibilities of the STAR panel are to:

1) Review draft stock assessment documents, data inputs, and analytical models, along with other pertinent information (e.g., previous assessments and STAR panel reports, when available);

2) Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting, work with the STATs to correct deficiencies, and, when possible, suggest new tools or analyses to improve future assessments; and

3) Develop STAR panel reports for all reviewed species to document meeting discussion and recommendations.

3.1 Review draft stock assessment documents, data inputs, and analytical models

Approximately two weeks before the STAR Panel meeting access to a web-site containing the draft Pacific Sardine Assessment Document and background material was granted. This was an excellent source on material from which to prepare for the actual review meeting. At the meeting, the SWFSC assessment team provided a good overview of the assessment approaches and the logic for their preference. Details were provided on each approach, survey design, analytical methods, and results during the meeting. This information greatly assisted the Review Panel in their review of assessment approach. When the Panel requested for a more detailed explanation or additional analysis the team generally provided the information the next day. The Panel and the CIE reviewers appreciated their efforts and acknowledge the extensive research effort to evaluate factors that may affect or bias outputs. The documented and presented information was sufficient to conduct the STAR Panel Review of the assessment and generally represents the best scientific information available at the moment. The ATM methodology Review to be held in 2018 will hopefully resolve the issues and recommendations associated with this assessment approach.

In general, the Panel review adhered to the agenda provided to attendees prior to the meeting. However, some flexibility was permitted by the chair when the discussion led into an area to be discussed later that was helpful to address the issue on-hand. Each CIE Reviewer participated in the discussion and review of the specific topics identified in the agenda and made a significant contribution to the Panel's draft summary report. The review chair collated the draft text and completed the Panel report with input from all Panel members. The review can be divided into 4 broad topics; the overview, acoustic-trawl surveys, the integrated assessment model (ALT), and conclusions/recommendations, each of which are discussed below.

3.2 Discuss the technical merits and deficiencies of the input data and analytical methods during the open review panel meeting.

The STAR Panel report provides a detailed summary of the Panel's views on the merits and deficiencies of both assessment approaches as well as suggestions to evaluated and potentially correct these deficiencies. Over the 3-day meeting, most areas of uncertainty or concern were addressed and where possible

additional information or data reruns were requested to improve the Panel's understanding of procedures and processes (Section 3.3.1).

In addition, specific issues were raised and are identified below.

3.2.1 Acoustic Trawl Method (ATM) survey.

There were a number of merits and deficiencies identified during the 2017 Star Panel Review for the Acoustic Trawl Method survey. Both the STAT and the STAR Panel agreed that the ATM likely provided the better approach to assess the NSP Pacific sardine stock in term of biomass. Unfortunately, the proposed approach to project the stock forward by about 1 year was deemed circular and performed poorly to other projection methods tested during the meeting. While the detailed discussion of the acoustic methods were deferred until the 2018 methods review, several areas of weakness in the survey approach were discussed (survey coverage, biological sampling, stratification, and ageing). Factors such as TS were not investigated but could have had a significant impact on the estimated biomass (assumed to be absolute). Herein lies another example of where some additional detail in the documentation could have helped. Target strength is a function of fish length and usually expressed in terms of total length for pelagic species. Yet, the length measured during the survey was standard length. Although not requested during the meeting, a simple statement indicating the TS equation was correct for length measurement would have clarified what was actually done.

Survey Coverage:

Survey coverage has been, and continues to be, a major issue for both the spring and summer acoustic surveys in that they do not provide complete coverage of the seasonal distribution of the species. Each year the fishing industry (Captains and representatives) reports a varying amount of Pacific sardine in the inshore waters not covered by the AT surveys. According to the industry representatives present at this year's Panel, large amounts of sardines were observed inshore over the last two years during the time of the survey that would not be accounted for by the survey. If these observations can be confirmed and quantified, it would complete the survey coverage, and likely increase the 1+ biomass of the Northern Pacific stock. Even the 2011 Panel Review, which acknowledged that the survey was adequate to provide an absolute biomass estimate for the area covered, suggested that methods be explored to obtain information, particularly on the inshore and to a lesser extent on the offshore areas.

From a personal point of view, this is an excellent opportunity for the STAT team and the SWFSC to explore collaboration opportunities for surveying with the fishing industry. A major challenge for the larger research vessels is the minimum

depth restrictions, imposed for safety reasons, limiting how close to shore the vessel can survey. Fishermen are general very familiar with local conditions and could, assuming a coordinated effort, provide coverage of those areas not covered by the survey vessel, thus eliminating the continuous uncertainty associated with what is and isn't in the inshore waters during the survey. Furthermore, there appears to be a sincere interest by the fishing industry to collaborate with the STAT team on surveying.

Another deficiency not directly related to spatial coverage, but the scope of the technology used to survey, is the amount of sardines distributed in the acoustic surface dead zone (10-15m below the surface). Currently, the surveys are conducted with hull mounted acoustic echo-sounders that can only detect fish directly under the vessel. Pacific sardines are commonly found very near the surface, thus any fish occurring in the dead zone would go undetected and would likely avoid the vessel, especially during the day. Recommendations have been made in previous reviews to investigate this section of the water column using sonar technology; however, no new information was presented at the review. The recommendation to use drone technology to address these and other areas of uncertainty are to be encouraged but they should not occur at the expense of more conventional technologies (e.g., sonar and aerial surveys).

Biological Sampling:

Biological Sampling appears to be another deficiency of the ATM. The current practice of surveying during the day and fishing during the night was again questioned. The assumption that fish present during the day are the same fish caught and occur with the same species composition (representative) is a major source of uncertainty. It should also be noted that a large number of the sets (Trawls) contain 0 catches (up to 50% in some years). Combine that with the pooling of sets into clusters and the actual sample size decreases substantially.

For this survey, the Primary Sampling Unit (PSU) is a cluster of sets undertaken in a general area. How the locations of the sets are determined is another area of uncertainty. It was curious to note that some clusters (multiple sets) occurred in areas where no fish were observed and no fish were caught. It was explained that because fishing occurred at night that fishing stations may or may not be in areas with fish. Given that the purpose of sampling is to determine species and size composition of the acoustic targets, fishing in areas without fish for multiple sets is somewhat futile. This practice of fishing for the sake of fishing also appears to be an inefficient use of precious vessel time. Better use of fishing time needs to be addressed and may help to improve biological sampling.

The species composition data from the sets are used to apportion the acoustic backscatter into species backscatter and subsequently into species specific biomass. Efforts should be made to improve (increase) biological sampling and reduce the uncertainty. This is another area where collaboration with the fishing

industry could benefit both science and the industry. Working with the fishing industry could remove some of the uncertainty associated with day surveying and night sampling if fishing vessels were used to confirm acoustic targets. Purse seines are generally non-size selective and in many cases the entire school can be caught, permitting additional sampling with an actual biomass estimate. Additional samples would also be available for ageing.

Ageing:

The Panel discussed a number of issues associated with the number of samples aged and the development of age-length keys related to both assessment approaches being reviewed. Probably most surprising to the Panel was the limited number of otoliths collected for a given AT survey. The number of fish sampled for age ranged from 16 to 1,051 per year, but were generally less than 500, especially in the most recent years. The explanation provided by the STAT was that samples were difficult to collect during the survey as the biomass was low. The Panel expressed concern about the application of so few ages to age length keys and the implication of this on the age and weight at length used for the models. Of particular concern was the practice of pooling samples from several years to create a generic ALK that was applied to the length distributions. Most fishery scientists frown (a must not do) upon this practice as it removes the effects of all inter-annual or density dependent growth variability. The generic ALK will also have an impact on all age-related factors associated with the assessment. Several unusual patterns were noted in the weight at age figures for a number of years. The only real solution is to increase the number of samples collected and to increase the number of otoliths retained for ageing so that sufficient otoliths are collected to generate an annual ALK. This is another area that should be explored where collaboration/coordination with the fishing industry could benefit both the resource and the analysis. Fishing vessels could be utilized to sample fish during the survey or to supplement low samples in specific areas where research samples are limited.

Post survey stratification:

The method used to post stratify the AT survey into stratum was unclear in the assessment report and caused several members of the Panel to express their concern about using the presence and density of fish to post stratify the survey area. A fair amount of discussion ensued on the approach, sampling design and the potential bias of using the latter two criteria to stratify the survey observations. Eventually, the actual procedure for increasing the intensity (spacing) of transects was explained and the Panel felt more comfortable with the approach. However, there were still uncertainties associated with how things were done and what triggered a change in transect spacing. This issue will be dealt with further by the second CIE Reviewer and under the recommendations

that should be addressed at the upcoming review of ATM scheduled for early 2018. Recommendation E states that the ATM survey design and estimation methods need to be more precisely specified.

3.2.2 Model-based assessment

The second assessment approach reviewed by the Panel was the model-based assessment (ALT) utilizing Version 3.24aa of the Stock Synthesis Assessment Toolbox to evaluate the status of the NSP of Pacific sardine stock. This model differs significantly in configuration and input parameters from the model used to update the assessment in 2016. Consequently, the requirement for a STAR Panel review. Changes include starting the model in 2005 (previously 1993) and excluding the Daily Egg Production Method (DEPM) and Total Egg Production (TEP) indices. Stock recruitment steepness and weight-at-age was pre-defined with the assumption that selectivity of the AT survey being 0 for age 0 and uniform for all other ages. Catchability was estimated under an age-based rather than a length-based model, ages modeled were reduced from 15 to 10 years and natural mortality increased from 0.4 to 0.6. Given that there is no directed fishery on the NSP resource so landings from the small live bait catches were included for 2015 and 2016 for the first time.

It was evident from the assessment document and presentations that the STAT team preferred the survey based method over the model-based approach to the assessment. The challenge for the preferred approach was to project forward almost a year from the last survey to the beginning of the management year. Thus, one of the key drivers in the review was to explore the method proposed by the STAT to estimate age 1+ biomass and its associated CV on July 1, 2017 from the ATM. If the proposed method was unacceptable then the Panel must identify the best approach to achieve and estimate biomass for management purposes.

Several inconsistencies, especially for age 0 were noted by the Panel in the outputs of the ALT model. A significant amount of time was spent on resolving issues associated with the ALT model. It appears that the seasonal option in the modelling (SS3) toolbox had not been fully tested and that it was producing unusual outputs related to the Age 0 fish. Several requests were made to the STAT team to try to resolve/understand these problems. Although not fully resolved to the satisfaction of the Panel, a work around process was established and projections for the 1+ biomass was available for the ALT model. Several approaches to estimate age 1+ biomass were explored by the Panel and are described below.

The first was to assume that the 1 July 2017 biomass equals the estimate of biomass from the summer 2016 ATM survey; simply ignoring mortality (natural causes and fishing), growth and recruitment from July 2016 to July 2017. This

method was considered as the simplest approach and the easiest to implement because it does not rely on a model or estimates of age composition for which sample sizes are low.

The second approach was to project the biomass from the 2016 ATM survey to 1 July 2017 taking into account mortality, growth and recruitment between July 2016 and July 2017. Unfortunately, the approach used to convert from length-composition to age-composition was incorrect, and the method used to derive the CV of age 2+biomass did not allow for uncertainty in the population age-composition, projected weight-at-age and maturity-at-age. In addition, the method relied heavily on model ALT because approximately half of the age 1+ biomass on 1 July 2017 consisted of age-1 animals. As such, the estimate of biomass is based to a substantial extent on the stock-recruitment function from model ALT. Finally, the value for M of 0.6yr-1 has no clear justification. The version of the projection model provided initially to the Panel did not account for catches, meaning that the procedure could not be applied in the future when the targeted sardine fishery re-opened. Furthermore, it did not account for the limited catches during 2016.

The third approach was to use the ALT model projections. The ALT Model has similar problems associated with the 'survey projection' model, i.e. the age-composition data are based on a year-invariant age-length key, and the basis for M=0.6yr-1 lacks strong empirical justification (and indeed likelihood profiles indicate some support for lower M than the value adopted for model ALT). In addition, the model presented to the Panel predicted age 0 catch in the ATM survey even though it is assumed that age-0 animals are not selected during the ATM survey. It appears that the model predictions of age-0 animals in the ATM survey are actually model-predicted numbers of age-1 animals that are predicted to be mis-read as age-0 animals. However, examination of the ATM survey length-frequencies suggests that that some age-0 animals (or animals that were spawning earlier in the year) are encountered during the surveys. The Model ALT also estimates Q to be 1.1, which is unlikely given some sardine are not available to the survey owing to being inshore of the survey area.

Finally, projections from the previous assessment model were examined. The model on which the 2014-16 assessments were based was approved for management by the 2014 STAR Panel. However, that assessment had some undesirable features, including extreme sensitivity to the occurrence of small (<~15cm fish) in the ATM surveys, poor fits to the length-composition and survey data, and sensitivity to initial values for the parameters (i.e. local minima) as noted in previous reviews. The Panel explored alternatives to the current selectivity formulation to better understand why model ALT was predicting age 0 catch when selectivity for age-0 fish was set to zero. It was noted that the results were generally robust assuming that selectivity is a logistic function of length (but that implies that some age-1+ animals are not available to the ATM survey),

allowing for time-varying age 0 selectivity, and estimating a separate selectivity pattern for ATM survey age-composition data.

The Panel noted that the 'survey projection' model and model ALT both rely on the samples from the ATM surveys to compute weight-at-age and survey age-composition data. The sample sizes for age from each survey were very small which means that estimates of, for example, weight-at-age are highly uncertain. The procedure of ensuring that weight-at-age for a cohort does not decline over time seems intuitively correct. However, if the estimated mean weight of young fish in a cohort is anomalously high owing to small samples, it can impact the weight-at-age of that cohort for all subsequent ages. When Model ALT steepness was estimated rather than fixing it equal to 0.8, the results were not sensitive to fixing versus estimating steepness, but the estimate of 0.36 was low.

In the end the Panel considered four ways to meet the management requirement to estimate age 1+ biomass on 1 July 2017: (1) the simple approach of using the of biomass estimate from the summer 2016 ATM survey without projecting forward, (2) projecting biomass from the 2016 ATM survey (summer) to 1 July 2017 using the proposed 'survey projection' model (and/or an alternative approach), (3) model ALT, and (4) the model on which the 2014-16 assessments were based. The Panel concluded that although neither method was fully acceptable that option 3, the ALT model, was likely the best available approach to meet the management needs.

3.3 Develop STAR panel reports for all reviewed species to document meeting discussion and recommendations.

This section summarizes the discussion and recommendations that form an integral part of the STAR Panel report. As a full member of the panel, I made a significant contribution to the preparation and editing of the final report. Consequently, I see no merit in rewording the sections related to requests for additional information, the recommendations and conclusions of the STAR panel report so I have extracted the appropriate sections and included them in my report. Although I fully agree with the content, there are a few areas where I have enhanced the text to complement that contained in the Panel report.

3.3.1 Requests made to the STAT (Taken Directly from the STAR Panel Report)

Day 1– Tuesday, February 21:

***Request 1*:** Provide documentation on the procedures used to calculate the survey age-composition data, including how age-length and age-biomass keys are constructed.

Rationale: These calculations are critical to projecting biomass after accounting for natural mortality, somatic growth, and recruitment; but the draft assessment document did not describe these calculations in sufficient detail for them to be reproduced. In addition, the age-compositions for the ATM survey in model ALT were computed using the method.

Response: Dr. Zwolinski presented written documentation and figures. The function "multinom" from the R package "nnet" fits a multinomial log-linear model using neural networks. The response is a discrete probability distribution (see Fig. 1). It is simpler to use than the alternative (sequential logistic models), and it provides a smoother transition between classes than an empirical age-at-length key. The age and lengths used for constructing the age-length key were from surveys from 2004 to the present. Due to the assumption of a July first date and its effect on ageing, the STAT built a season-specific age-length key using data pooled across time separately for spring/summer.
The Panel agreed that aggregation across years is not appropriate if some length-classes represent multiple ages, which is the case for Pacific sardine. Moreover, substantial spatial and temporal variation occurs in size-at-age, and smoothing this out by merging the data from several years creates bias in annual estimates of age compositions of varying magnitude and direction.

Request 2: Provide full specification, including equations, of the calculations used to 1) project from the ATM survey biomass estimate to the estimated age 1+ biomass on July 1 of the following fishing year, and 2) calculate the uncertainty associated with that biomass estimate.

Rationale: The projection calculations need to be reproducible. Management advice (Overfishing Level OFL, Acceptable Biological Catch ABC, and Harvest Guideline HG) for Pacific sardine requires an estimate of age 1+ biomass (OFL, ABC, HG) and its uncertainty (ABC) on July 1, 2017.

Response: For 1), Dr. Zwolinksi walked the Panel through a spreadsheet that made these calculations and the Panel agreed that the calculations were sensible, conditional on the age-weight key. For 2), assuming independence of age- 1 and age- 2+ biomass, the total variance was calculated by summing the respective variances. This calculation is negatively biased because it ignores uncertainty in age-composition and weight-at-age. It was noted that the resultant coefficient of variation (CV) for age 1+biomass is lower than the CV for either component (age- 1 versus age- 2+) due to their assumed independence.

Request 3: Plot cohort-specific rather than year-specific growth curves (weight-at-age) for the ATM survey and overlay raw data/information on sample sizes. Make it clear which values are estimated versus inferred. Do this for the fisheries data as well.

Rationale: Cohort-specific curves are easier to interpret as growth trajectories than year-specific curves. It is important to understand how much data drives these estimates, and to understand the consequences of applying the same age-length key for all years with survey data to calculate the weight-at-age and age-composition for the ATM survey.

Response: Dr. Hill presented tables including sample sizes and estimated means for each cohort-season-age combination. The tables were formatted to highlight entries that were inferred versus estimated. Dr. Hill calculated means whenever three or more samples were available. However, these means were sometimes overwritten based on the assumption that animals did not shrink. The ATM data showed substantial variation in weight-at-age across years (Fig. 2), and possibly increasing size-at-age in recent years. The MexCal catch data appeared less variable overall, and it was noted that fishery sample sizes were generally larger than the ATM sample sizes. An error was discovered in the weight-at-age data for the PNW catch, which could not be resolved during the Panel meeting.

The Panel noted that the adopted method ended up discarding data for cohorts with unusually large mean sizes for age-0 fish by not allowing "shrinkage", whereas it may have been the age-0 means that were anomalous rather than the means calculated for older ages. The Panel also noted that in many cases, the sample sizes were very small. The weight-at-age key used within the survey-based projection did not exclude "shrinkage". Using the weight-at-age key in model ALT produced an imperceptible difference in model-estimated age 1+ biomass.

Request 4: Verify that model ALT was run with ATM survey selectivity set equal to 0 for age-0 fish. Contact Dr. Rick Methot to better understand how selectivity is being modeled under the chosen selectivity option in SS.

Rationale: The model outputs appear to indicate that the model predicts non-zero catches of age-0 fish despite the intent to specify selectivity to be 0 zero on age-0 fish. This may have significant unintended consequences for the likelihood calculations.

Response: This question was not fully resolved. It appears that Stock Synthesis predicts some catch of nominal "age- 0" even given selectivity of zero on true age-0 fish because aging error leads to the expectation that some age-1 fish will be caught and miscategorized as age- 0. Further model runs revealed that the model "blew up" if aging error was set to zero or made

very small, but reductions in the specified aging error led to the expected reduction in the predicted age-0 catch. It was noted that surveys likely include a mix of age-1 fish miscategorized as age-0, as well as fish that are truly age-0.
Dr. Methot also noted that Stock Synthesis had not been as thoroughly debugged for semester-based models as for strictly annual models.
See also Requests 5, 8, and 9.

Request 5: Re-run model ALT with age- 0 fish removed from the input file for the ATM survey.

Rationale: Similar to Request 4, the model likelihood should not be influenced by data on age-0 fish if it is assumed selectivity on age-0 fish is zero, but the model appears to be generating non-zero predictions and comparing these against the input data.

Response: The model still predicted catch of age-0 fish in this scenario. This is consistent with the explanation suggested for this pattern under Request 4.

Request 6: Report the CV of the estimate of terminal biomass based on changes in how the compositional data are weighted.

Rationale: The weighting of compositional data appeared to have little effect on the point estimate of biomass, but it is important to understand implications of alternative weighting schemes for uncertainty as well.

Response: Data weighting increased the CV by 2-3%. The base model had a CV of approximately 36%, Francis-weighting led to a CV of approximately 38%, and harmonic mean weighting led to a CV of about 39%.

Request 7: Show more outputs from T_2017 and T_2017_No_New_AT _Comp

Rationale: These outputs would help the Panel evaluate the reasons for proposing a move away from a strict update of the previously accepted model structure, i.e. identify problems with a strict update that the new model structure addresses.

Response: Selectivity curves for the spring and summer ATM surveys were noticeably different depending on whether the two most recent survey length-compositions were included in the assessment or not (Fig. 3). These models appeared to yield acceptable fits to abundance indices, but the fits to observed length-compositions were poor. It appears that the model estimates very low selectivity on small fish for the summer survey (since selectivity does not vary across years, and very few small fish are encountered most years) such that when small fish are encountered, they are expanded to a very large

number. During Panel discussion, it was noted that this unexpected behavior should not happen if selectivity were forced to be the same for the spring and summer surveys.

Day 2 – Wednesday, February 22

Request 8: Develop a model in which selectivity for age-0 animals in the survey is time-varying.

Rationale: The availability of age-0 animals to the survey seems to be highly variable among years, but influential on the results. A selectivity function in which age-0 selectivity varies among years should "discount" the influence of occasional catches of age-0 animals.

Response: A model was presented that assumed essentially full selection on age-1+ animals, and time-varying age-0 selectivity. The model estimated nearly zero selectivity on age-0 fish in all years except 2015, when estimated selectivity on age-0 fish was nearly 1.0. Fits to compositional data were similar to those for model ALT, except that the spike of age-0 fish in 2015 was captured better. The estimate of age 1+biomass on 1 July, 2017 for this model was 77,845 t.

Request 9: Run a variant of model ALT in which the age-compositions are assigned to a new fleet (6) that has logistic selectivity (estimated separately for the spring and summer periods).

Rationale: Selectivity for the ATM survey is assumed to be uniform on animals aged 1 and older so age-composition data are not required for this survey. The selectivity pattern for the trawl component of the survey is not uniform on age-1+ animals (some age-0 animals are caught) and it may be possible to represent this using a logistic selectivity function.

Response: This model performed generally similarly to a double-logistic formulation applied to the ATM survey for both age-composition and as an abundance index, but it misses the summer 2016 ATM survey estimate of biomass from above, whereas the double-logistic fits that estimate closely. The double-logistic model had a negative log-likelihood of approximately 311, compared to 305 for this variant and 333 for model ALT. Thus, both a model with logistic ATM selectivity and a model that assumed 1+ selectivity for ATM survey estimates and logistic selectivity for the associated age-composition data fit the data somewhat better than model ALT.

Request 10: Conduct a retrospective evaluation of how well alternative assessment methods can predict the biomass from the summer ATM surveys. For each year Y for which there is a summer ATM survey estimate for year Y and year Y+1, report predictions of year Y+1 biomass based on (a)

the estimate of biomass from the results of the ATM survey during summer of year Y, (b) the estimate of biomass based on applying the projection method to the results from the ATM survey in summer of year Y, and (c) model ALT based on data through year Y.

Rationale: The Panel wished to understand which method was able to predict the ATM survey estimate of biomass most accurately.

Response: The STAT provided results for the three selected approaches as well as the estimates of age 1+ biomass obtained by projecting the actual assessments used for 2012, 2013, 2014 and 2015 forward ("Past assessments" in Fig. 4) and estimates of age 1+ biomass obtained by projecting the model used for 2014, 2015 and 2016 management advice ("2014 formulation"). Model ALT generally came closest to predicting the survey biomass estimate the following year, doing so by a substantial margin for 2014. "Past assessment" was usually the worst. Model ALT had the lowest residual variance. Relative errors were a CV of 1.07 for Model ALT, 1.26 for the 2014 model on which 2014, 2015 and 2016 management advice was based on formulation, 1.50 for the last survey without projection, 1.62 for the values adopted in management specifications, and 1.70 for projections from the past previous ATM survey (see Appendix 2 for the specifications for the method).

Day 3 – Thursday, February 23

Request 11: Develop a method for estimating recruitment solely from ATM data, explain how these recruitment estimates could be used to project forward from an ATM biomass estimate, and then add results for that method to the retrospective comparison described in Request 10.

Rationale: During discussion of Request 10, it was clear that much of the concern regarding the currently proposed method of projecting from the survey was its dependence on model ALT for inputs, resulting in its dependence on the same assumptions the STAT was hoping to avoid by moving away from an integrated assessment. It was pointed out that it could be possible to develop estimates of age 1 biomass on 1 July, 2017 strictly from the ATM data.

Response: The STAT modified the survey projection method so that projected biomass of 1-year-olds was the average over the most recent five years. As desired, this approach was not tied to the model ALT. However, the residual standard deviation for this approach ("Survey projection 2"), while better than "Survey projection", was still worse than Model ALT and the 2014 model formulation (1.45) (Fig. 4).

4.0 Recommendation and Conclusions

One of the primary objectives of the stock assessment process and the STAR Panel Review was to provide advice to management on 2017-2018 NSP Pacific sardine resource using the best available information/data. The Panel reviewed multiple options, described above and concluded for 2017 that, given the current management approach requires an estimate of age-1 biomass at the start of July, model ALT was the best approach at present for conducting this assessment notwithstanding the concerns listed above. The results from the assessment are robust to changes in how selectivity is modelled, the value for steepness and data weighting, but there were several concerns with this model that could not be resolved during the Panel meeting. Assuming uniform selectivity leads to lower estimates of current 1+ biomass, but this assumption reflects the expectation that all fish in the survey area are vulnerable to detection during an acoustic survey.

The STAT strongly recommends that management advice for Pacific sardine be based on the estimates of biomass from the ATM survey rather than a projection model or an integrated assessment. The STAR Panel is in general agreement with this approach and notes the following ways in which management could be based on the ATM survey results given the July 1 biomass estimate requirement. The first would be to change the start-date of the fishery so that the time between conducting the survey and the implementation of harvest regulations is minimized. And, secondly to use Management Strategy Evaluation to evaluate the risk to the stock of basing management actions on an estimate of biomass that could be a year old at the start of the fishing season (if the fishery start date is unchanged). Review of an updated MSE would likely not require a Methodology Panel, but could instead be conducted by the SSC.

The Panel further notes that there may be benefits to attempting to use both the spring and summer ATM surveys as the basis for an ATM survey-only approach and that moving to an assessment approach that relies on the most recent ATM survey (or two) may be compromised by reductions in ship time and/or problems conducting the survey. From the CIE Reviewer perspective, the reduction of vessel time will have implications for the AT survey and at a minimum will increase the variance estimates of biomass and the uncertainty about survey coverage.

The Panel agrees with the STAT that there is value in continuing to collect biological data and to update model ALT even if management moves to an ATM survey-only approach.

4.1 Research Recommendations:

The Panel identified a number of research recommendations that have been prioritized in three categories: High, medium and low.

High priority

A. Conduct an analysis of effect of fish sample size on the uncertainty in the ATM biomass estimates and model outputs. Use this information to re-evaluate and revise the sampling strategy for size and age data that includes target sample sizes for strata.
B. The clusters (the Primary Sampling Units, PSUs) with age-length data should be grouped into spatial strata (post-strata, or collapsed post-strata used in ATM biomass estimators). The variance in estimates of age-length compositions can then be estimated by bootstrapping of PSUs, where age-length keys are constructed for each bootstrap replicate. The sub-sample size of fish within clusters that are measured for lengths should be increased, and length-stratified age-sampling should be implemented. This approach would likely increase coverage of age samples per length class and reduce data gaps.
C. The survey projection method should be developed further. Specifically, the survey age-composition should be based on annual age-length keys, and the uncertainty associated with population age-composition, weight-at-age and maturity-at-age needs to be quantified and included in the calculation of CVs. A bootstrapping procedure could be used to quantify the uncertainty associated with population age-composition and projected weight-at-age. Uncertainty in weight-at-age could also be evaluated using a retrospective analysis in which the difference between observed and predicted weight-at-age for past years was calculated. Ultimately, improved estimates of weight-at-age and measures of precision of such estimates could be obtained by fitting a model to the empirical data on weight-at-age.
D. The methods for estimating 1 July age 1+ biomass based on the results of the ATM survey during the previous year currently use only the results of the summer survey. Improved precision is likely if the results from the spring and summer surveys were combined. This may become more important if the number of days for surveying is reduced in the future. Consideration should be given to fish born after 1 July.
E. Investigate alternative approaches for dealing with highly uncertain estimates of recruitment that have an impact on the most recent estimate of age-1+ biomass that is important for management.
F. Modify Stock Synthesis so that the standard errors of the logarithms of age-1+ biomass can be reported. These biomasses are used when computing OFLs, ABCs and HGs, but the CV used when applying the ABC control rule is currently that associated with spawning biomass and not age-1+ biomass.
G. The approach of basing OFLs, ABCs and HGs for a year on the biomass estimate from the ATM survey for the previous year should be examined using MSE so the anticipated effects of larger CVs and a possible time-lag

between when the survey was conducted and when catch limits are implemented on risk, catch and catch variation statistics can be quantified.

H. The assessment would benefit not only from data from Mexico and Canada, but also from joint assessment activities, which would include assessment team members from both countries during assessment development.
I. The assessment would benefit from the availability of estimates of 1+ biomass that include quantification of the biomass inshore of the survey area and in the upper water column.
J. It is unclear how the habitat model is applied to determine survey design. Is this an *ad hoc* decision or is there a formal procedure? The next Panel should be provided with comprehensive documentation on how the habitat model is applied.
K. Consider future research on natural mortality. Note that changes to the assumed value for natural mortality may lead to a need for further changes to harvest control rules.
L. Explore the potential of collaborative efforts to increase sample sizes and/or gather data relevant to quantifying effects of ship avoidance, problems sampling near-surface schools, and currently un-sampled nearshore areas.
M. Reduce aging error and bias by coordinating and standardizing aging techniques and performing an aging exchange (double blind reading) to validate aging and estimate error. Standardization might include establishing a standard "birth month" and criteria for establishing the presence of an outer annuli. If this has already been established, identify labs, years, or sample lots where there is deviation from the criteria. The outcome of comparative studies should be provided with every assessment.

Medium priority

N. Continue to explore possible additional fishery-independent data sources such as the SWFSC juvenile rockfish survey and the CDFW/CWPA cooperative efforts (additional sampling and aerial surveys). Inclusion of a substantial new data source would likely require review, which would not be easily accomplished during a standard STAR Panel meeting and would likely need to be reviewed during a Council-sponsored Methodology Review.
O. Consider spatial models for Pacific sardine that can be used to explore the implications of regional recruitment patterns and region-specific biological parameters. These models could be used to identify critical biological data gaps as well as better represent the latitudinal variation in size-at-age; this should include an analysis of age-structure on the mean distribution of sardine in terms of inshore-offshore (especially if industry partner-derived data were available).
P. Consider a model that has separate fleets for Mexico, California, Oregon-Washington and Canada.

Q. Compare annual length-composition data for the Ensenada fishery that are included in the MexCal data sets for the northern sub-population with the corresponding southern California length compositions. Also, compare the annual length-composition data for the Oregon-Washington catches with those from the British Columbia fishery. This is particularly important if a future age data/age-based selectivity model scenario is further developed and presented for review.

Low priority

R. Consider a model that explicitly models the sex-structure of the population and the catch.

S. Develop a relationship between egg production and fish age that accounts for the duration of spawning, batch fecundity, etc., by age. Using this information in the assessment would require that the stock-recruitment relationship in SS be modified appropriately.

T. Change the method for allocating area in the DEPM method so that the appropriate area allocation for each point is included in the relevant stratum. Also, apply a method that better accounts for transect-based sampling and correlated observations that reflects the presence of a spawning aggregation.

4.2 Recommendations that should be addressed during the 2018 review of the ATM survey

The Panel was informed that a methodology review of the ATM approach was scheduled for January 2018. Because of this, a number of issues and detailed discussions regarding this approach were deferred until the review. However, the Panel did make several recommendations, listed below, that should be considered for the 2018 review.

A. In relation to the habitat model:

a. Investigate sensitivity of the assessment to the threshold used in the environmental-based method (currently 50% favourable habitat) to further delineate the southern and northern subpopulations of Pacific sardine.

b. Further validate the environmentally-based stock splitting method. The habitat model used to develop the survey plan and assign catches to subpopulation seems to adequately predict the spawning/egg distribution in the CalCOFI core DEPM region, but eggs were observed where they were not expected in northern California, Oregon and Washington during one of the two years when the survey extended north. It may be possible to develop simple discriminant factors to differentiate the two sub-populations by comparing metrics from areas where mixing does not occur. Once statistically significant discriminant metrics (e.g. morphometric, otolith morphology, otolith micro-structure, and possibly using more recent developments in genetic methods) have been chosen,

these should be applied to samples from areas where mixing may be occurring or where habitat is close to the environmentally-based boundary. This can be used to help set either a threshold or to allocate proportions if mixing is occurring.

c. Consider including environmental covariates in model-based approaches that would account quantitatively for environmental effects on distribution and biomass. The expertise from a survey of fishermen could be extremely useful in identifying covariates that impact the distribution of clusters.

B. The SWFSC plans to examine ship avoidance using aerial drone sampling; there is an ongoing significant effort by Institute of Marine Research in Norway to understand the same issue using sonar, and the SWFSC acoustics team should communicate and coordinate with those researchers.

C. The effect of population size affecting the number and spacing of school clusters likely affects the probability of acoustic detection in a non-linear way; this could create a negatively biased estimate at low population levels and potentially a non-detection threshold below which the stock size cannot be reliably assessed. A simulation exercise should be conducted using the current, decreased and increased survey effort over a range of simulated population distribution scenarios to explore this.

D. The consequences of the time delay and difference in diurnal period of the acoustic surveys versus trawling need to be understood; validation or additional research is critical to ensure that the fish caught in the trawls from the night time scattering layer share the same species, age and size structure as the fish ensonified in the daytime clusters.

E. The ATM survey design and estimation methods need to be more precisely specified. A document must be provided to the ATM review (and future assessment STAR Panels) that:

- delineates the survey area (sampling frame);
- specifies the spatial stratification (if any) and transect spacing within strata planned in advance (true stratification);
- specifies the rule for stopping a transect (offshore boundary);
- specifies the rules for conducting trawls to determine species composition;
- specifies the rule for adaptive sampling (including the stopping rule); and
- specifies rules for post-stratification, and in particular how density observations are taken into account in post-stratification. Alternative post-stratification without taking into account density should be considered.

DISCLAIMER

The information in this report has been provided for review purposes only. The author makes no representation, express or implied, as to the accuracy of the information and accepts no liability whatsoever for either its use or any reliance placed on it.

Appendix I: Background material

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Appendix II: Statement of Work for Dr. Gary Melvin

Statement of Work
National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) Center for Independent Experts (CIE) Program External Independent Peer Review
STAR Panel Review of the 2017-2018 Pacific Sardine Stock Assessment
February 21-24, 2017

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards.
(http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The CIE reviewers will serve on a Stock Assessment Review (STAR) Panel and will be expected to participate in the review of Pacific sardine stock assessment. The Pacific sardine stock is assessed regularly (currently, every 1-2 years) by SWFSC scientists, and the Pacific Fishery Management Council (PFMC) uses the resulting biomass estimate to establish an annual harvest guideline (quota). The stock assessment data and model are formally reviewed by a Stock Assessment Review (STAR) Panel once every three years, with a coastal pelagic species subcommittee of the SSC reviewing updates in interim years. Independent peer review is required by the PFMC review process. The STAR Panel will review draft stock assessment documents and any other pertinent information for Pacific sardine, work with the stock assessment teams to make necessary revisions, and produce a STAR Panel report for use by the PFMC and other interested persons for developing management recommendations for the fishery. The PFMC's Terms of Reference (ToRs) for the STAR Panel review are attached in Appendix 1. The tentative agenda of the Panel review meeting is attached in Appendix 2. Finally, a Panel summary report template is attached as Appendix 3.

Requirements

Two CIE reviewers shall participate during a panel review meeting in La Jolla, California during 21-24 February, and shall conduct impartial and independent peer review accordance with the SoW and ToRs herein. The CIE reviewers shall have the expertise as listed in the following descending order of importance:

- The CIE reviewer shall have expertise in the design and execution of fishery-independent surveys for use in stock assessments, preferably with coastal pelagic fishes.
- The CIE reviewer shall have expertise in the application of fish stock assessment methods, particularly, length/age-structured modeling approaches, e.g., ‘forward-simulation’ models (such as Stock Synthesis, SS) and it is desirable to have familiarity in ‘backward-simulation’ models (such as Virtual Population Analysis, VPA).
- The CIE reviewer shall have expertise in the life history strategies and population dynamics of coastal pelagic fishes.
- It is desirable for the CIE reviewer to be familiar with the design and application of fisheries underwater acoustic technology to estimate fish abundance for stock assessment.
- It is desirable for the CIE reviewer to be familiar with the design and application of aerial surveys to estimate fish abundance for stock assessment.

The CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review process.

Tasks for reviewers

• Review the following background materials and reports prior to the review meeting: *Two weeks before the peer review, the NMFS Project Contact will send by electronic mail or make available at an FTP site to the CIE reviewers all necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE on where to send documents. The CIE reviewers shall read all documents in preparation for the peer review, for example:*

• *Recent stock assessment documents since 2013;*
    • *STAR Panel- and SSC-related documents pertaining to reviews of past assessments;*
    • *CIE-related summary reports pertaining to past assessments; and*
    • *Miscellaneous documents, such as ToR, logistical considerations.*

Pre-review documents will be provided up to two weeks before the peer review. Any delays in submission of pre-review documents for the CIE peer review will result in delays with the CIE peer review process, including a SoW modification to the schedule of milestones and deliverables. Furthermore, the CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein.

• Attend and participate in the panel review meeting • The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to provide any additional information required by the reviewers, and to answer any questions from reviewers

• After the review meeting, reviewers shall conduct an independent peer review in accordance with the requirements specified in this SOW, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus
• Each reviewer may assist the Chair of the meeting with contributions to the summary report, if required by the TORs
• Deliver their reports to the Government according to the specified milestone dates

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign

National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration- system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and at the Southwest Fisheries Science Center in La Jolla, California.

Period of Performance

The period of performance shall be from the time of award through April 30, 2017. Each reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables

The contractor shall complete the tasks and deliverables in accordance with the following schedule.

No later than January 24, 2017	CIE sends reviewers contact information to the COTR, who then sends this to the NMFS Project Contact
No later than February 7, 2017	NMFS Project Contact sends the CIE Reviewers the pre-review documents
February 21-24, 2017	The reviewers participate and conduct an independent peer review during the panel review meeting
March 10, 2017	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
March 31, 2017	CIE submits CIE independent peer review reports to the COTR
April 7, 2017	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:
(1) The reports shall be completed in accordance with the required formatting and content (2) The reports shall address each TOR as specified (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Annex I: Review Panel Agenda

Revised AGENDA
2017 Pacific Sardine Stock Assessment Review

Southwest Fisheries Science Center
8901 La Jolla Shores Dr., La Jolla, CA 92037
La Jolla, CA 92037
858-334-2800

This is a public meeting, and time for public comment may be provided at the discretion of the meeting Chair. This is a work session for the primary purpose of reviewing the current Pacific sardine stock assessment, under the Pacific Fishery Management Council's (Council) terms of reference for the CPS stock assessment reviews. The Stock Assessment Review Panel will review the assessment and produce a report to the full SSC, in advance of the April 2017 Council meeting in Sacramento, California. The assessment will be used for setting sardine harvest specifications and management measures for the July 1, 2017 – June 30, 2018 fishery.

TUESDAY, FEBRUARY 21, 2017 – 10 A.M.

A. Call to Order, Introductions, Approval of Agenda André Punt, Chair
(10 a.m., 15 minutes)

B. Terms of Reference for CPS Stock Assessment Review Process Kerry Griffin
(10:15 a.m., 15 minutes)

C. Pacific Sardine Stock Assessment Team Presentation Overview Paul Crone
(10:30 a.m., 15 minutes) Kevin Hill

D. Acoustic-Trawl Survey Juan Zwolinski
(10:45 a.m., 45 minutes)

E. Pacific Sardine Stock Assessment Team Presentation Kevin Hill
(11:30 p.m., 1 hour 30 minutes) Paul Crone

LUNCH
(1 p.m. – 3p.m., 2 hours)

NOTE: The Pacific Room is needed for another purpose from 1 p.m. until 3 p.m. The STAR Panel and attendees can move to Stenella Meeting room during this time.

E. Pacific Sardine Stock Assessment Team Presentation (continued if needed) Kevin Hill
(3:00 p.m., 30 minutes) Paul Crone

F. Discussion and Requests Panel
(3:30 p.m., 1 hour 30 minutes)

WEDNESDAY FEBRUARY 22, 2017

G. Work Session – STAT and STAR Panel All
(8 a.m., 2 hours)

H. Public Comment
(10 a.m., 0.5 hours)

I. Response to Requests Kevin Hill
(10:30 a.m., 1.5 hours)

LUNCH

J. Initial Report Writing and STAT Work Session Panel
(1 p.m., 2.5 hours)

K. Discussion and Requests Panel
(3:30 p.m., 1 hour)

L. Public Comment André Punt
(4:30 p.m., 0.5 hours)

THURSDAY FEBRUARY 23, 2017

M. Response to Requests Kevin Hill
(8 a.m., 2 hours)

BREAK

N. Discussion and Requests Panel
(10:30 a.m., 1.5 hours)

LUNCH

O. Response to Requests Kevin Hill
(1 p.m., 1 hour)

P. Public Comment
(2 p.m., 0.5 hours)

BREAK

Q. Report Writing and STAT Work Session
(3 p.m., 2 hours)

FRIDAY FEBRUARY 24, 2017

R. Response to Comments (If Necessary) Kevin Hill
(8 a.m., 1 hour)

S. Discussion – Next Steps and Deadlines André Punt
(9 a.m., 1 hour) Kerry Griffin

BREAK

T. Finalize Report Assignments André Punt
(10:30 a.m., 1.5 hours)

U. Work Session as Necessary and Meeting Wrap Up André Punt
(12:00 p.m.)

ADJOURN

Appendix III: List of Participants

STAR Panel Members:
André Punt (Chair), Scientific and Statistical Committee (SSC), Univ. of Washington
Will Satterthwaite, SSC, Southwest Fisheries Science Center
Evelyn Brown, SSC, Lummi Natural Resources, LIBC
Jon Vølstad, Center for Independent Experts (CIE)
Gary Melvin, Center for Independent Experts (CIE)

Pacific Fishery Management Council (Council) Representatives:
Kerry Griffin, Council Staff
Diane Pleschner-Steele, CPSAS Advisor to STAR Panel
Lorna Wargo, CPSMT Advisor to STAR Panel

Pacific Sardine Stock Assessment Team:
Kevin Hill, NOAA / SWFSC
Paul Crone, NOAA / SWFSC
Juan Zwolinski, NOAA / SWFSC

Other Attendees
Dale Sweetnam, SWFSC
Alan Sarich, CPSMT/Quinault Indian Nation
Emmanis Dorval, SWFSC
Chelsea Protasio, CPSMT/CDFW
Kirk Lynn, CPSMT/CDFW
Ed Weber, SWFSC
Josh Lindsay, NMFS WCR
Erin Kincaid, Oceana
Al Carter, Ocean Gold
Jason Dunn, Everingham Bros Bait
Nick Jurlin, F/V Eileen
Neil Guglielmo, F/V Trionfo
Andrew Richards, Commercial
Hui-Hua Lee, SWFSC
Bev Macewicz, SWFSC
Chenying Gao, Student
Steven Teo, SWFSC
Kevin Piner, SWFSC
Andy Blair, Commercial
Jamie Ashley, F/V Provider
John Budrick, CDFW
Steve Crooke, CPSAS
Gilly Lyons, Pew Trusts